

Aerobic Denitrification: Implications for Nitrogen Fate Modeling in the Missouri-Ohio-Mississippi (MOM) River Basin

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Each year, about 1.6 million metric tons of nitrogen, mostly from agriculture, are discharged from the lower Mississippi/Atchafalaya River Basin into the Gulf of Mexico, and each spring this excess nitrogen fuels the formation of a huge hypoxic zone in the Gulf. In the Mississippi, as well as most nitrogen-degraded rivers and streams, nitrate (NO_3^-) is the dominant N species, and therefore understanding its biogeochemical behavior is critical for accurate nitrogen fate modeling.

Nitrate is highly mobile in the environment and readily available to microorganisms. Nitrate is removed from the biologically available pool by denitrification, a step-wise biochemical reduction: $\text{NO}_3^- \rightarrow \text{NO}_2^- \rightarrow \text{NO} \rightarrow \text{N}_2\text{O} \rightarrow \text{N}_2$. Conventional thought long has held that nitrate reduction, or denitrification, does not take place when oxygen is present. However, based on thermodynamic modeling of data representing samples from natural freshwater systems, dissolved O_2 and NO_3^- were reduced to nearly equal redox potentials in every sample we analyzed, suggesting simultaneous reduction of O_2 and NO_3^- .

In an effort to evaluate implications of these thermodynamic data experimentally, five headspace-recirculating microcosm reactors were constructed using engineered glass jars, copper tubing, and a peristaltic pump. An O_2 -saturated, sterile, synthetic river water solution (0.13 mM NO_3^-) was added to the reactors aseptically, along with three different inoculums taken from (1) natural river water, (2) wetland surface water, and (3) wetland sediment slurry. Two sterile controls were also employed.

The reactors were sealed, and headspace gas, originally of atmospheric composition, was recirculated through the solution. Within approximately three weeks, the N_2O concentration in the headspace increased greater than fivefold, while the nitrate concentration in the slurry decreased concomitantly. At the end of the experiment, the dissolved O_2 concentration in the slurry was approximately that of water equilibrated with atmospheric O_2 .

Although aerobic denitrification recently has been shown to take place under non-environmental conditions, such as sewage treatment facilities where NO_3^- and C_{org} are very concentrated, to our knowledge, this is the first work to report aerobic denitrification under conditions typically found in environmental settings, such as the Missouri–Ohio–Mississippi (MOM) River Basin. Our discovery of aerobic denitrification is expected to have a high impact on nitrogen fate modeling, as most existing models call for denitrification to take place in anoxic settings, yet most impacted surface waters are aerobic.

Disclaimer: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

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